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(54) Electric cables having flexible polyolefin insulation

(57) Insulation for an electric power or control cable is made by blending pellets of polyethylene and ethylene propylene copolymer, antioxidant and cross-linking agent without any mineral reinforcing filler and passing the blended mixture through a screw extruder which simultaneously homogenizes and extrudes the ingredients to coat an electrical conductor.

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SPECIFICATION

Electric cables having flexible polylolefin insulation

This invention is concerned with electric power and control cables having flexible polyolefin insulation and with methods of making said insulation.

For such cables, cross linked polyethylene insulation is too stiff, particularly in high voltage cables which require a thick layer of insulation. Copolymers of polypropylene have electrical properties substantially equal to those of polyethylene, but do not have the necessary physical strength and have to be filled with clay or other filler that provides the required strength but degrades the electrical characteristics. Unfilled chemically cross linked polyethylene has long been recognized by the power cable industry as an insulating material characterized by very low dielectric losses, high dielectric strength, and excellent physical properties. Its most undesirable properties are relatively high hardness and minimum flexibility. Installation costs increase substantially due to the longer time involved making splices and terminations. Compositions based upon ethylene-propylene copolymers, and terpolymers and other elastomers have found application in power cables because of their inherently greater flexibility and ease of installation, substantially reducing those costs.

Ethylene-propylene rubbers have been amorphous materials and required reinforcement from added fillers such as hard calcined clays to achieve their necessary physical strength to be used in insulation. Polyethylene, being crystalline in structure, does not require additional reinforcement, therefore unfilled compositions are practical and are used in most power cable applications above 2 kV rating. An unfilled polymer system provides the highest degree of electrical properties, and conversely, the addition of fillers detracts from the inherently good electrical properties of ethylene-propylene rubbers in proportion to the amount of filler employed.

From one aspect, the present invention provides a method of making a layer of insulation for an electric cable which comprises mixing together pellets of polyethylene and ethylene propylene copolymer, antioxidant and cross-linking agent in which the ingredients are mixed non-homogenously, in a ribbon blender in the absence of any mineral reinforcing filler in the ribbon blender, then introducing the blended polymer ingredients and the antioxidant and cross-linking agents into an extruder housing having a feed screw in the extruder housing as the ingredients are advanced through said extruder housing by the feed screw, simultaneously homogenizing and extruding the ingredients to coat an electrical conductor with the mixture of polyethylene, and the copolymer of ethylene and propylene, said copolymer being approximately 15% crystalline, and containing no filler that increases the physical properties of the insulation, adding to said coopolymer polyethylene to supply additional crystallinity to the insulation, the polyethylene forming with said ethylene-propylene co-polymer, a polymer system having electrical characteristics substantially equal to those of polyethylene and having improved physical characteristics of greater toughness than the copolymer, and greater flexibility than poly-ethylene.

From another aspect, an electric cable according to the invention comprises an electric cable including in combination a conductor, and a layer of insulation surrounding the conductor and comprising a mixture of polyethylene and ehtylene propylene copolymer in proportions between approximately 80:20 and 20:80, and both of which are cross-linked, the cable being a high voltage cable with a semi-conducting layer of extruded material between the conductor and the insulation, and another layer of semi-conducting material around the outside of the insulation, the mixture of polyethylene and ethylene propylene copolymer comprising a polymer system which constitutes the insulation of the cable having the polyethylene serving to give the ethylene propylene copolymer the needed physical properties, including a viscosity low enough to be extruded over the semi-conducting layer of processing temperature with the ethylene propylene copolymer being substantially free of any filler for imparting improved physical properties to the ethylene propylene copolymer, the ethylene propylene copolymer imparting improved flexibility to the insulation as compared with insulation consisting of cross-linked polyethylene.

In the present invention, both the highest degree of electrical characteristics of an unfilled polymer system and the inherent flexibility of rubber have been combined into a composition suited to power cable applications which include both low and high voltage varieties. This has been accomplished by physically combining polyethylene and an ethylene propylene copolymer or ethylene propylene terpolymer together with a suitable antioxidant and a peroxide curing agent to bring about a cross-linked composition. The ratios in the polymer system can be varied to provide more or less flexibility as desired without appreciably altering other physical properties and without signifiant changes in electrical characteristics. The resultant compounds are inherently tough, flexible and of the highest degree of electrical properties comparable to those of a typical unfilled chemically cross-linked polyethylene. The cross-linking itself can also be achieved in the absence of chemical cross-linking by irradia-

done on the pellets by the screw in the extruder barrel softens the pellets and thoroughly mixes the materials of the pellets together so that they are fluxed into each other forming a complete homogenous matrix.

If additional ingredients, such as an antioxidant and peroxide curing agent, are added to the pellets, these additional ingredients diffuse through the walls of the pellets, and mix with the polyethylene and ethylene propylene copolymer without waiting for the pellets to be fluxed into each other by the extruder.

The conductor 12 passes through the extruder head via a guider tip, and the insulation is extruded over the conductor at the tip in accordance with conventional extrusion practice.

This invention permits an improvement in the extrusion process which has not been possible with insulation made entirely of ethylene propylene rubber and filler.

The insulating material can be forced through a fine mesh screen or plate in the extruder at a location between the end of the screw and the tip of the extruder. The mixture of the two base polymers, polyethylene and ethylene propylene copolymer, can be forced through a screen having the equivalent of a 325 mesh, and this eliminates from the insulation any solid impurities 1.7 mils in size. The elimination of particles larger than 1.7 mils, or the breaking-up of the particles which do pass through the screen, greatly increases the effectiveness of the insulation by making it capable of withstanding higher voltage stress per mil of insulation thickness.

The preferred material for the ethylene propylene copolymer is available from Exxon Chemical Co., PO Box 201, Florham Park, New Jersey 07932. The particular copolymer that has been used for the material described in this specification is designated by the Exxon Chemical Co. as "Vistalon 702", and it is approximately 15% crystalline. Exxon Chemical Co. makes another copolymer of ethylene and propylene designated as "Vistalon 404" whcih has substantially no crystallinity. This amorphous copolymer cannot be used for the present invention because it requires a filler in order to have the strength necessary for the insulation.

An equivalent material to that described in the specification is a copolymer of an ethylene and propylene in which diene is added to make a terpolymer. This material designated as "Nordel 2722" is available from DuPont of Wilmington, Delaware. For purposes of the appended claims, this Nordel 2722, without filler, is to be considered a mechanical equivalent of the copolymer of ethylene and propylene with some crystallinity. There may also be other products which are chemical equivalents of the copolymers of ethylene and propylene with crystallinity sufficient for making insulation when mixed with polyethylene and without any filler in the insulation.

The expression "ethylene propylene copolymer" is used herein in a broad sense to include such copolymers even though additional copolymerized monomer may be present, as in the Nordel ethylene diene terpolymer described above.

The expression "unfilled" as used herein, designates an insulation in which no material, for example clay, has been added to the insulation compound for the purpose of increasing the mechanical strength of the insulation. Such filler degrades the electrical characteristics of the insulation.

The preferred embodiments of the invention have been illustrated and described, but changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the appended claims.

CLAIMS

1. A method of making a layer of insulation for an electric cable which comprises mixing together pellets of polyethylene and ethylene propylene copolymers, antioxidant and cross-linking agent in which the ingredients are mixed non-homogeneously, in a ribbon blender in the absence of any mineral reinforcing filler in the ribbon blender, then introducing the blended polymer ingredients and the antioxidant and cross-linking agents into an extruder housing having a feed screw in the extruder housing as the ingredients are advanced through said extruder housing by the feed screw, simultaneously homogenizing and extruding the ingredients to coat an electrical conductor with the mixture of polyethylene, and the copolymer of ethylene and propylene, said copolymer being approximately 15% crystalline, and containing no filler that increases the physical properties of the insulation, adding to said copolymer polyethylene to supply additional crystallinity to the insulation, the polyethylene forming with said ethylene-propylene copolymer, a polymer system having electrical characteristics substantially equal to those of polyethylene and having improved physical characteristics of greater toughness than the copolymer, and greater flexibility than polyethylene.

2. A method as claimed in claim 1 comprises mixing polymer pellets of the copolymer of ethylene and propylene, and pellets of polyethylene, all of the polymers being of electrical insulation grade with a cross-linking agent and an antioxidant, homogenizing the mixture and extruding the mixture over a core of a cable and then cross-linking the flexible polymer system.

3. A method as claimed in either claim 1 or claim 2 in which the insulation is made without using a non-polymer filler for increasing the physical strength of the insulation, and the crystallinity of the copolymer and

die of the extruder.

11. An electric cable including in combination a conductor, and a layer of insulation surrounding the conductor and comprising a mixture of polyethylene and ethylene propylene copolymer in proportions between approximately 80:20 and 20:80, and both of which are cross-linked, the cable being a high voltage cable with a semi-conducting layer of extruded material between the conductor and the insulation, and another layer of semi-conducting material around the outside of the insulation, the mixture, of polyethylene and ethylene propylene copolymer comprising a polymer system which constitutes the insulation of the cable having the polyethylene serving to give the ethylene propylene copolymer the needed physical properties, including a viscosity low enough to be extruded over the semi-conducting layer at processing temperature with the ethylene propylene copolymer being substantially free of any filler for imparting improved physical properties to the ethylene propylene copolymer, the ethylene propylene copolymer imparting improved flexibility to the insulation as compared with insulation consisting of cross-linked polyethylene.

12. An electric cable as claimed in claim 11 comprising a metal shield outside of the insulation, and an outer jacket over the metal shield.

13. An electric cable as claimed in either of claims 11 or 12 comprising an emission shield surrounding the semi-conducting layer that is between the conductor and the insulation, the emission shield being located between said semi-conducting layer and the inside surface of the insulation.

14. An electric cable as claimed in any of claims 11 to 13 in which the insulation includes polyethylene and ethylene propylene copolymer in the proportions between approximately 60:40 and 40:60, and both of which are cross-linked themselves and to each other.

15. An electric cable as claimed in any of claims 11 to 14 in which the insulation, when at extrusion temperature, is of such viscosity that it can be forced through a fine mesh screen of a 325 mesh, and the insulation is free of solid impurities larger than about 1.7 mils.

16. An electric cable as claimed in any of claims 11 to 15 in which the ethylene propylene rubber is a terpolymer of ethylene and propylene and a third co-monomer.

17. A method of making insulation for an electric cable substantially as described with reference to the accompanying drawings.

18. An electric cable substantially as described with reference to the accompanying drawings.

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